The background.

With energy costs rising again, there is renewed interest in temperate regions in the use of double-cladding with polyethylene for energy conservation. Heat loss can be reduced by separating two coverings by air pressure maintained by a small continuously running fan. Two different films are sometimes used in more conventional houses. For example, in Spain an internal EVA copolymer film on the greenhouse roof is being increasingly used below polyethylene film to reduce heat loss at night[1].

The total worldwide area of inflated greenhouses in 2003 is estimated at 3,000 square miles. Approximately 65% of all commercial greenhouses in the United States use the air-inflated system[2]. An air-inflated double layer of plastic has shown a fuel savings of 25 to 40 percent over the use of a single layer of plastic[3]. According to Djevic and Dimitrijevic, also, double-layer polyethylene covered greenhouses can consume 40% less fuel than single polyethylene covered[4]. Double polycarbonate panels will have approximately 50% lower heat requirements than single layer greenhouses.

In spite of these advantages, there are some questions that must be considered such as effect of reducing CO_2 concentration, reduced nutrient uptake, internal air pollution, etc. These can lead to lower production quality and quantity. The main disadvantage of double poly over glass was the measured light reduction of 18 percent[5]. On the plus side the average winter daytime relative humidity was 12 percent higher. The small crop production reduction was offset by the fuel savings. Crops not requiring high light levels would do well under this covering arrangement.

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[1] D.W. Robinson & B.Brae. 1991. **Developments in plastic structures and materials for horticultural crops**. http://www.agnet.org.

[2] A.J. Both, D. Mears and E. Reiss. **The Air-Inflated Double-Layer Polyethylene Greenhouse.** Rutgers University, Bioresource Engineering.

[3] D. Ross. **Energy conserving greenhouse modifications**. Cooperative extension service. University of Maryland.

[4] M.Djevic and A.Dimitrijevic. Greenhouse energy consumption and energy efficiency. http://www.ru.acad.bg.

[5] A.J. Both, D. Mears and E. Reiss. **The Air-Inflated Double-Layer Polyethylene Greenhouse.** Rutgers University, Bioresource Engineering.

Demonstration set up and results.

The inflated greenhouses have the advantage of losing internal heat at a slower rate. This is supposed to have a positive effect on plant growth, as it is possible to maintain higher internal average temperatures as compared to traditional greenhouses. AAC intervention aimed the introduction of inflated greenhouses in the most intensive greenhouse production areas of Albania, as an energy efficient alternative, in order to expand the growing season, and thus creating premium price opportunities.

Four demonstration plots were settled, respectively in; Berat (Gorican), Fier (Velmish) and Lushnje (Hysgjokaj, 2 different sites). Good farmers were selected based on a share cost agreement. Each plot a 1000 sq. m greenhouse was constructed. Each inflated and a common control greenhouse a set of data loggers was installed.

The expected outcomes of the proposed technology included;

1. Improved operational efficiency.
    a. Faster maturity/early harvest due to warmer growing environment.
    b. Higher percent of marketable fruit due to minimal loss from cold weather.
    c. Lower operating costs, as compared to traditional greenhouse heating systems.
2. Expanded market opportunity (earliness).
3. Increased farmer's revenues due to early/late sales.
4. Increased profit due to price premium.

The planned parameters to be recorded included;

- temperature and humidity fluctuations,
- days to first flowering, days to first/last harvest,
- the incidence of pests and diseases,
- marketable yield and the respective prices.

In order to estimate the microclimate differences between conventional and inflated greenhouses air humidity and air temperature data collected from data loggers were analyzed. Because during the light hours sun radiation is able to accumulate enough energy inside any greenhouse, analyses was focused to dark hours (from 17^{00} to 4^{00}), where due to significant energy losses, plants might be threaten in cold nights.

There was no significant difference in air humidity. Both greenhouses, greenhouse air was saturated (99.9 % humidity) alongside all night hours. Of course, there is a risk for high incidence of fungal diseases, but in fact no serious disease problems were occurred during the cropping cycle.

Contrary to that, the differences regarding to air temperatures were significant. Tables 1 and 2 shows the respective temperature of conventional and common greenhouses during night hours in one of demonstration sites (Hysgjokaj 1). Similar results were obtained all other sites. Obviously, at the beginning of dark period there is a much higher temperature in inflated greenhouses (5.7 ^{0}C). The advantage is maintained throughout the night, though gradually diminished (Fig. 1). The mean of temperature differences between conventional and inflated greenhouses (12 night hours) was calculated to about 2 Celsius degree. One should note that practically, even the conventional greenhouses were equipped with a plastic ceiling (a common farmer's practice), which has somehow a similar effect with inflated greenhouse coverings. Because of that, one should count a higher temperature difference between the pure conventional and inflated greenhouses.

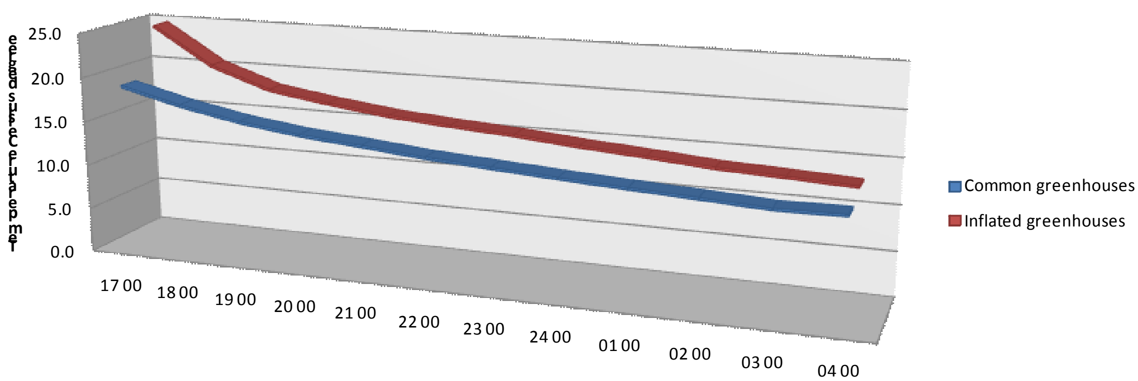
Table 1. Hourly air temperatures of traditional greenhouses (Hysgjokaj 1) during night time.

Data / Time	4/4/2009	5/4/2009	6/4/2009	8/4/2009	9/4/2009	10/4/2009	11/4/2009	12/4/2009	13/4/09	15/4/09	lourly average
17 00	19.7	16.8	19.2	18.3	18.3	19.5	20.9	20.4	20.3	15.8	18.92
18 00	18	16.4	18.5	17.6	16.3	17.3	18	18	17.6	14.7	17.24
19 00	17.2	15.8	16.5	16.8	15	15.8	16.3	16.2	16	13.9	15.95
20 00	16.6	15.5	15.1	16.5	13.9	14.5	15.1	14.9	14.6	13.8	15.05
21 00	15.8	15.5	14.3	16.2	13.1	13.7	14	14.5	13.6	13.8	14.45
22 00	15.3	14.5	13.5	14.9	13.7	13	13	13.8	12.7	13.5	13.79
23 00	16.2	14.5	12.9	13.5	14	12.7	12.3	12.7	11.9	12.7	13.34
24 00	15.9	14.3	12.3	12.4	14.5	11.9	11.7	12.3	11.2	12.5	12.9
01 00	15.9	13.8	12.4	11.6	14.2	11.3	11.3	11.5	10.4	12.6	12.5
02 00	15.6	14	12.2	11	13.8	10.7	10.9	10.9	9.9	12.5	12.15
03 00	15.4	14	11.6	10.4	13.4	10.3	10.5	10.4	9.6	12	11.76
04 00	15.4	13.5	11.6	10.2	12.9	10.3	11.1	10.9	10.1	12.4	11.84

Table 2. Hourly air temperatures of inflated greenhouses (Hysgjokaj 1) during night time.

Data / Time	4/4/2009	5/4/2009	6/4/2009	8/4/2009	9/4/2009	10/4/2009	11/4/2009	12/4/2009	13/4/09	15/4/09	Hourly average
17 00	25.7	25.9	24.4	27.3	26.1	23.4	26.9	24.1	18.7	23.4	24.6
18 00	22.2	21.2	20.5	21.7	21.6	19.7	20.7	20.2	17.1	19.1	20.4
19 00	20.2	19.7	18	18.7	18.4	17.5	17.3	18.7	16	16.5	18.1
20 00	18.8	19.5	17.4	17.2	16.8	16	15.9	17.9	15.5	15.6	17.1
21 00	17	18.8	16.9	16.1	15.9	15.1	14.7	17.6	15.3	14.6	16.2
22 00	16	18.4	16.5	15.2	15.2	14.5	14	17.3	15.2	14.2	15.7
23 00	15.3	18	15.8	14.5	14.6	14.5	13.5	17	15.1	13.6	15.2
24 00	14.7	17.7	14.6	14	14	13.7	13	16.8	14.2	13	14.6
01 00	14.2	17.4	13.8	13.6	13.6	13.2	12.5	16.4	13.6	12.4	14.1
02 00	13.6	16.3	13	13.1	13.2	12.9	12	15.3	13.6	11.9	13.5
03 00	13.7	16.1	12.4	12.5	12.9	12.4	11.7	15.1	13.6	11.5	13.2
04 00	13.4	16.3	11.8	12	12.7	12	11.4	14.4	13.2	11.2	12.8

Fig. 1. Temperature gradient of common and inflated greenhouses.



The heat required can easily be calculated for a given construction, shape and covering material of a greenhouse. These values represent amount of heat that has to be applied to the greenhouse each hour in order to maintenance the desired temperature, if the heater is located in the greenhouse. The amount of fuel needed for a given period of time, can be calculated knowing the heat value of the fuel, the thermal efficiency of the burner and heat required for a given greenhouse[6].

Considering that a difference of 2 to 4 Celsius degree was evidenced between common and double plastic greenhouses, one can easily calculate the differences of total heat losses between them (Table 3). Obviously, the heat losses are significantly reduced in case of inflated greenhouses, in the range from 19 000 to 39 000 kcal per hour. This mean that due to a better energy conservation inside the inflated greenhouses, a similar effect of that of burning 2 to 4 l/hr of heating oil was naturally obtained. The total benefit throughout the growing season would be equal to the burning effect of 19 000 to 39 000 liters of heating oil per 1000 sq. m greenhouse.

[6] A.Balliu. 2004. **Mjediset e mbrojtura**. UBT.

Providing the current market oil prices, the difference of 2 to 4 Celsius degree obtained due to double plastic film coverings would cost from 200 000 to 450 000 ALL.

Table 3. Heat loss calculations from conventional and inflated greenhouses and assumed heating costs differences in case of heater would be installed inside the greenhouses.

Greenh. type.	Greenh. area (m^2)	Temp. difference (outside-inside greenh., ^{0}C)	Heat loss (kcal/hr)	Oil consumpt. (L/hr)	Total fuel consupt. (L)	Assumed heating cost (ALL)
Common	1000	12	117600	11.8	160584	1375920
Inflated (2^0C)	1000	10	98000	9.8	8820	1146600
Inflated (4^0C)	1000	8	78400	7.8	7056	917280
Difference 2^0C	1000		19600	2	1764	229320
Difference 4^0C	1000		39200	4	3528	458640

Similarly with our own calculations, table 4. shows calculated heating requirements (outside assumed temperature -18^{0}C, inside greenhouse temperature 20^{0}C) for most common greenhouse structures and materials used in Serbia and Montenegro region[7]. The amount of fuel needed for heating in this case (each greenhouse 264 sq. m), if fuel oil is used, as it is given in table 4, is much less in double plastic greenhouses.

Table 4. Heat requirements (kW) and fuel consumption (l/h) for two types of greenhouses (single plastic and double plastic)[8].

Greenhouse type	Heat requirements (kW)		Fuel needed (l/h)	
	Quonset	Arch	Quonset	Arch
Single plastic	103	107	8.9	9.3

[7] M.Djevic and A.Dimitrijevic. **Greenhouse energy consumption and energy efficiency**. http://www.ru.acad.bg.

[8] Data adopted from Djevic and Dimitrijevic.

Double plastic	72	75	6.2	6.5

The increased inside temperature have a considerable effect on development rate of greenhouse's crops. As a consequence the harvesting has started 4 to 6 days before, but more than that, the harvesting rate of first weeks was much higher in inflated greenhouses. This resulted at the end with higher yield and better market price (Table 5).

Table 5. Crop production data of common conventional greenhouses versus inflated greenhouses in different demonstration sites.

Site	Crop	Data	Common greenhouse	Inflated greenhouse.
1	Cucumber	Planting date	February 7	February 6
		First harvest	April 2	April 10
		Yield (ton/1000 sq. m)	15	14
		Average price (ALL/ton)	55000	40000
2	Melon	Planting date	March 15	March 14
		First harvest	May 18	May 22
		Yield (ton/1000 sq. m)	7.2	7.2
		Average price (ALL/ton)	57000	45000
3	Tomato	Planting date	February 10	February 11
		First harvest	April 22	April 25
		Yield (ton/1000 sq. m)		
		Average price (ALL/ton)		

Previous data[9,10], where a similar increase on inside temperature greenhouse were obtained due to passive heating systems, confirm its significant positive effect on fruit maturity and earliness. As it might be seen from the graphs below, the first harvest of tomato and French bean started almost one week before in greenhouses where the inside temperature was from 2

[9] A.Balliu & E.Cota. 2005. **Alternativa ekologjike te prodhimit ne serra**.

[10] H.Kuci. 2006. **Vleresimi i pershtatshmerise se rajoneve gjeografike per ndertimin e serrave dhe i efektivitetit te shfrytezimit te sistemeve passive diellore**. Master thesis. UBT.

to 4 Celsius degree higher, compared to conventional greenhouses. The total yield recorded was also up to 28 % higher (French bean).

Thanks to faster crop development due to higher temperatures, a higher harvesting rate was recorded at the beginning of harvest season (Figure 2 and 3, Table 6). Because of both factors, improved earliness and higher harvesting rate at the beginning of season, the farmers were rewarded by a higher market price and consequently, a much higher market revenue, up to 60 % in case of French bean, was achieve.

Fig. 2. Tomato harvesting rate of improved greenhouse (red) versus common greenhouse.

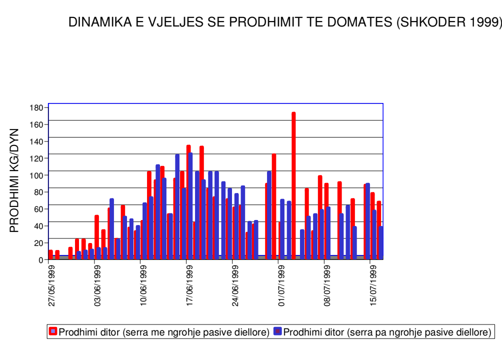


Fig. 3. French bean harvesting rate of improved greenhouse (red) versus common greenhouse.

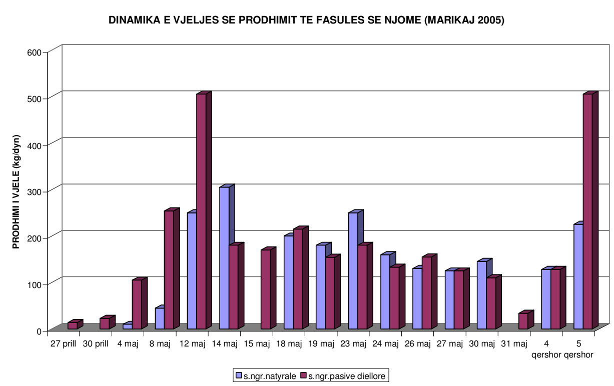


Table 6. Harvesting rate and market revenues of improved greenhouses (2-4 ^{0}C higher temperatures inside) versus common greenhouses planted with French bean.

Data	Harvested yield (kg/dyn)			Market revenues (ALL)	
	Common greenhouse	Improved greenhouse	Market price (L/kg)	Common greenhouse	Improved greenhouse
27 Apr		14	400	0	5600
30 Apr		23	360	0	8280
4 May	10	105	320	3200	33600
8 May	45	254	240	10800	60960
12 May	250	505	160	40000	80800
14 May	305	180	160	48800	28800
15 May		170	150	0	25500
18 May	200	215	130	26000	27950
19 May	180	154	120	21600	18480
23 May	250	180	100	25000	18000

24 May	160	133	110	17600	14630
26 May	130	155	90	11700	13950
27 May	125	125	70	8750	8750
30 May	145	110	50	7250	5500
31 May		34	50	0	1700
4	128	128	35	4480	4480
5	225	505	35	7875	17675
Total	**2153**	**2990**	**108 / 125**	**233055**	**374655**

There is of course a higher construction cost of inflated greenhouses, due to double amount of plastic films and additional labor. As it might seen in Table 7, the construction cost of inflated greenhouses is close to 15000 Euro/ha higher compared to traditional farmer's constructed greenhouses.

Assuming there will be two cropping per year (first cucumber and then tomato), even by assuming no increase in production yield, the inflated greenhouses would provide much better economical results, simply due to higher market prices because of earlier and late production. In the timeframe of ten years utilization (which corresponds with full greenhouse depreciation) the net profit value (NPV) of an inflated greenhouse is calculated about 93 000 euro/ha versus about 60 000 euro/ha of common greenhouses (Table 8 and Table 9). One might consider that as an additional profit of about 30 000 euro per ha. The internal rate of investment return (IRR) is also obviously much better for inflated greenhouses; 34 % versus 29 % of common greenhouses. Producing in inflated greenhouses would also be safer for farmers, since the production break even would be 12.77 kg/sq.m versus 16,07 kg/sq.m of common greenhouses (Table 7).

Table 7. Main production and economic indicators of common versus inflated greenhouses.

	Common greenhouse	Inflated greenhouse
Construction investment (Euro/1 ha)	49136	64496
Yield first crop (cucumber kv/ha)	1023	1023
Market price first second crop (ALL/kv)	5806	6290
Yield second crop (tomato kv/ha)	750	750
Market price second crop (ALL/kv)	4600	4800
Break even yield (kg/m2)	16,07	12,77
Break even price (Euro/m2)	0,36	0,32

CONVENTIONAL GREENHOUSES

Table 8. Financial return on investment (Euro)

Planted area 10000 m2

	-6 month	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
A. Investments costs											
Greenhouse	45296	0	0	0	10240	0	0	10240	0	0	10240
Other facilities	3840	0	0	0	0	0	0	0	0	0	0
Total investments costs	**49136**	**0**	**0**	**0**	**10240**	**0**	**0**	**10240**	**0**	**0**	**10240**
B. Operating costs											
Operating costs	0	53417	53417	53417	53417	53417	53417	53417	53417	53417	53417
Interest rate											
Total operating costs	**0**	**53417**	**53417**	**53417**	**53417**	**53417**	**53417**	**53417**	**53417**	**53417**	**53417**
Total outflows (A+B)	**49136**	**53417**	**53417**	**53417**	**63657**	**53417**	**53417**	**63657**	**53417**	**53417**	**63657**
C. Incomes											
Sales incomes	0	70752	70752	70752	70752	70752	70752	70752	70752	70752	70752
Total inflows	**0**	**70752**	**70752**	**70752**	**70752**	**70752**	**70752**	**70752**	**70752**	**70752**	**70752**
Financial analysis											
Net cash flow	-49136	17335	17335	17335	7095	17335	17335	7095	17335	17335	7095
NPV	59748										
IRR	0.29										

INFLATED GREENHOUSES

Table 9. Financial return on investment (Euro)

Planted area 10000 m2

	-6 month	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
A. Investments costs											
Greenhouse	57696	0	0	0	20480	0	0	20480	0	0	20480
Other facilities	6800	0	0	0	0	0	0	0	0	0	0
Total investments costs	**64496**	**0**	**0**	**0**	**20480**	**0**	**0**	**20480**	**0**	**0**	**20480**
B. Operating costs											
Operating costs	0	53570	53570	53570	53570	53570	53570	53570	53570	53570	53570
Interest rate											
Total operating costs	**0**	**53570**	**53570**	**53570**	**53570**	**53570**	**53570**	**53570**	**53570**	**53570**	**53570**
Total outflows (A+B)	**64496**	**53570**	**53570**	**53570**	**74050**	**53570**	**53570**	**74050**	**53570**	**53570**	**74050**
C. Incomes											
Sales incomes	0	80280	80280	80280	80280	80280	80280	80280	80280	80280	80280
Total inflows	**0**	**80280**	**80280**	**80280**	**80280**	**80280**	**80280**	**80280**	**80280**	**80280**	**80280**
Financial analysis											
Net cash flow	-64496	26710	26710	26710	6230	26710	26710	6230	26710	26710	6230
NPV	93118										
IRR	0.34										

Discussion and recommendations.

Double plastic films, inflated greenhouses, resulted to be a highly efficient and feasible option for fresh vegetable producers. Due to double covering and additional insulation effect of air separates plastic films, higher minimum and average air temperatures were available throughout growing season. The effect would be equal to energy might be released by burning out an amount of up to 3500 litter /1000 sq. m of heating oil. Converting the conventional greenhouses to inflated ones is not a heavy duty. Supposing that 25% of current greenhouse area in Albania will shift to inflated models, i.e., 200 ha, the benefit of technology would be equal to energy released by burning out 1400 ton heating oil per year. The additional profit would be no CO_2 release, at all.

A faster development rate was provided to cultivated crops and consequently the earliness and harvesting rate of first pickings were significantly improved. Farmers were rewarded by better prices and consequently higher market revenues were achieved. By expanding the technology, an extension of production cycle (earlier and late production), is expected and consequently the competitiveness of Albanian product in the regional markets will get improved. The positive effect of better insulation of inflated greenhouses could be improved by equipping them with passive solar heating systems. The most appropriate passive solar systems and the feasibility of combination with inflated greenhouses should be searched / demonstrated in the next coming years.

It was expected a certain reduction of light intensity inside inflated greenhouses, but no evidences were available about the negative effects on plant production. One can assume that in spring season with an abundant amount of sun light, the negative effect of reduced light intensity were compensated by higher (especially minimum) temperatures. Considering the fact that the Albanian farmers are used to extensive use of low tunnels inside the greenhouses, inflated greenhouses should be considered as a proper alternative to improve the common practice, which has a stronger negative effect on plant lightening.

Some problems related with greenhouse ventilation might rise up. Different types of inflated greenhouses (shape, gutter height, windows rate, and windows position) should be developed / demonstrated in order to find out the most appropriate version for specific climatic conditions of Albanian regions.

Since it is an effective investment, on the benefits of farmers and competiveness of Albanian agricultural products, promotion and development of inflated greenhouse should be supported. It is recommended that construction of inflated greenhouses to be included in the subsidy scheme of MOAFCP (Payment Agency), at the level of additional cost compared to construction of common conventional greenhouses (15000 Euro/ha).